

# DIANA

## Dual Ion Accelerators for Nuclear Astrophysics

DIANA – An underground accelerator facility for  
nuclear astrophysics status report



Daniel Robertson  
University of Notre Dame

- DIANA community
- Science requirements and goals
- Chosen location
- Technical overview
- Status
- What next?



# DIANA community

## Dual Ion Accelerators for Nuclear Astrophysics

Creation of underground accelerator laboratory as a NSF user facility for study of nuclear astrophysics

University of Notre Dame (Lead institution)

Colorado School of Mines

Lawrence Berkeley National Laboratory

Michigan State University

University of North Carolina

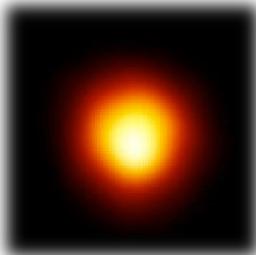
South Dakota School of Mines

- 7 additional institutions identified as users

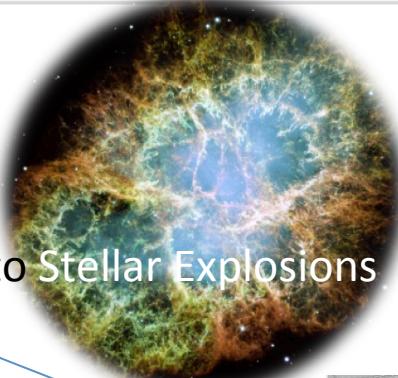
# Accelerators underground

Alessandra's, Tuesday Talk

Astrophysics from



Stars to Stellar Explosions



From Astro-Biology



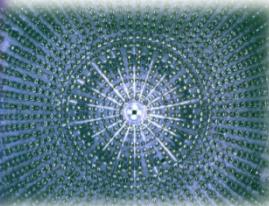
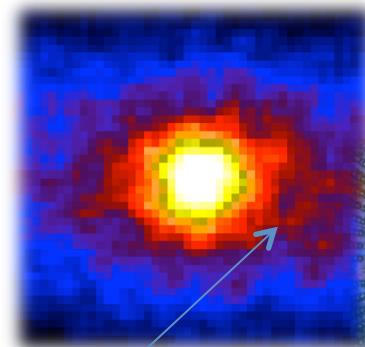
To Exo-Planets

Plasma physics

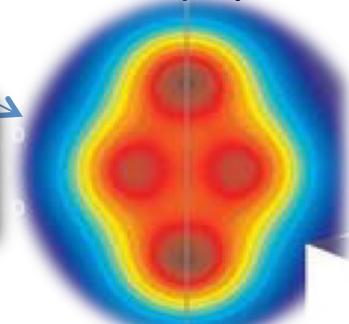


The interface of atomic and nuclear interaction

Neutrino physics  
Translating observations  
into results

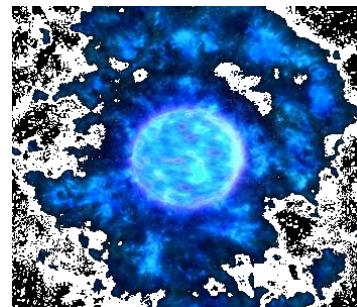
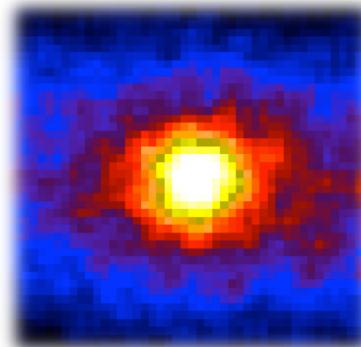


Nuclear structure physics

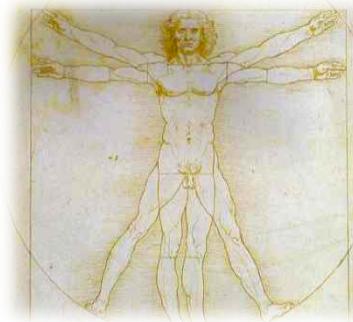
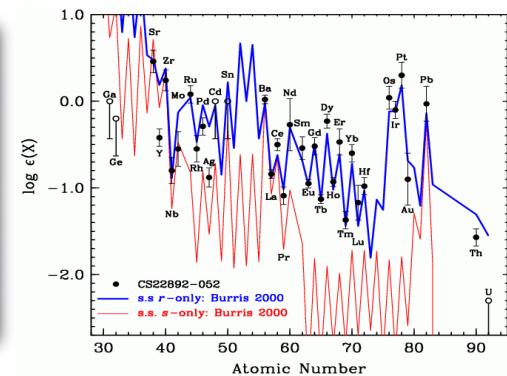
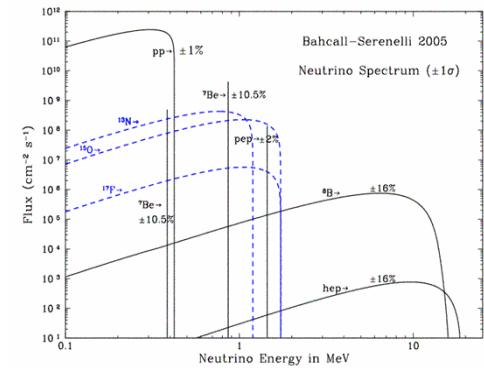


# Science goals

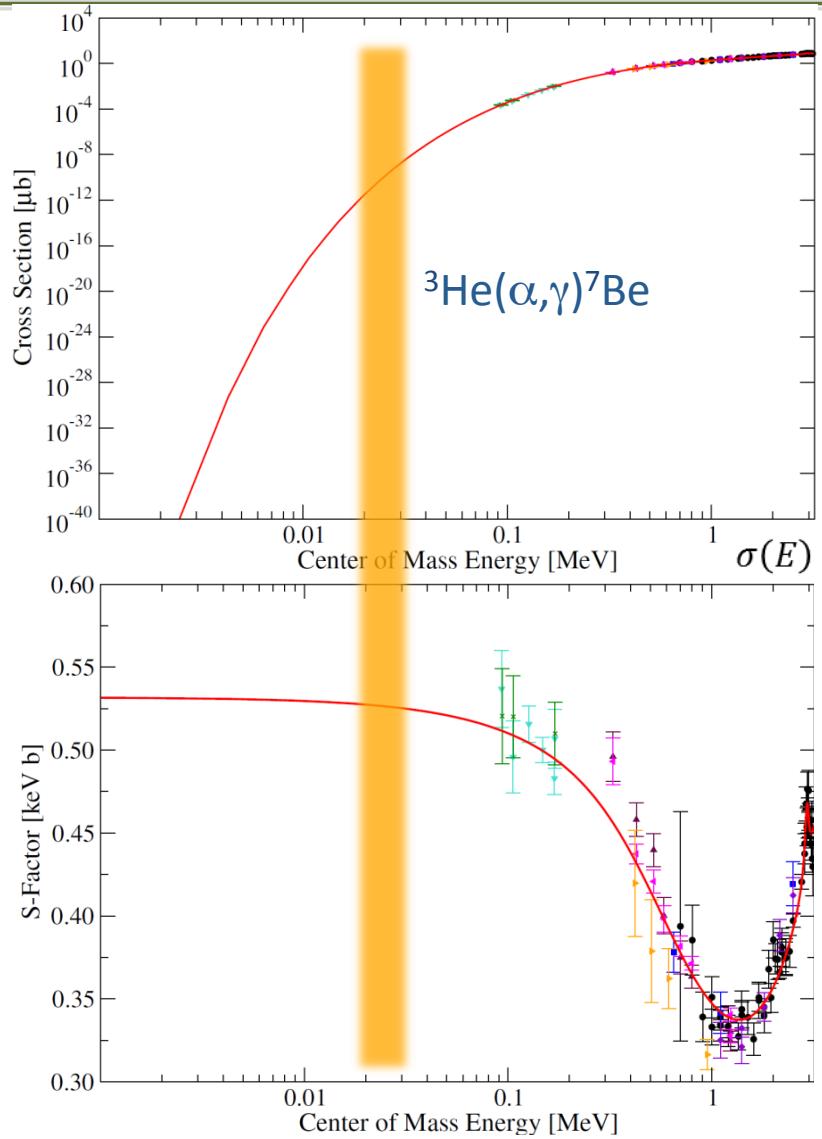
- Metallicity of solar core and the structure of our Sun
- Neutron sources for heavy element production in late stellar evolution (s-process)
- Carbon nucleosynthesis and the foundation of biological life in the universe



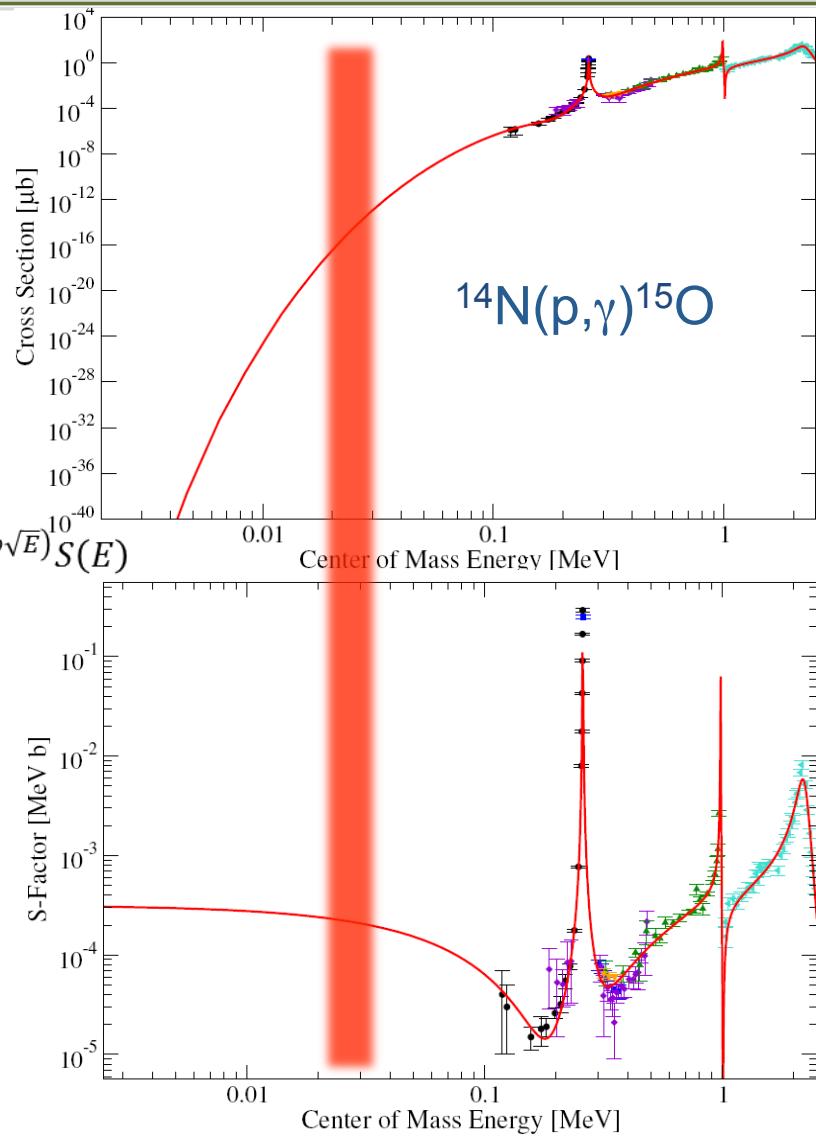
Alessandra's, Tuesday Talk



# Radiative capture reactions

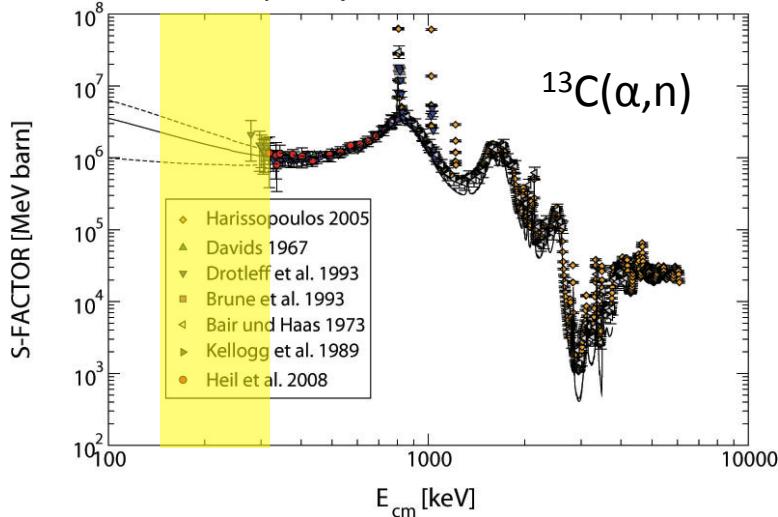


$$\sigma(E) = \frac{1}{E} e^{(-b\sqrt{E})} S(E)$$

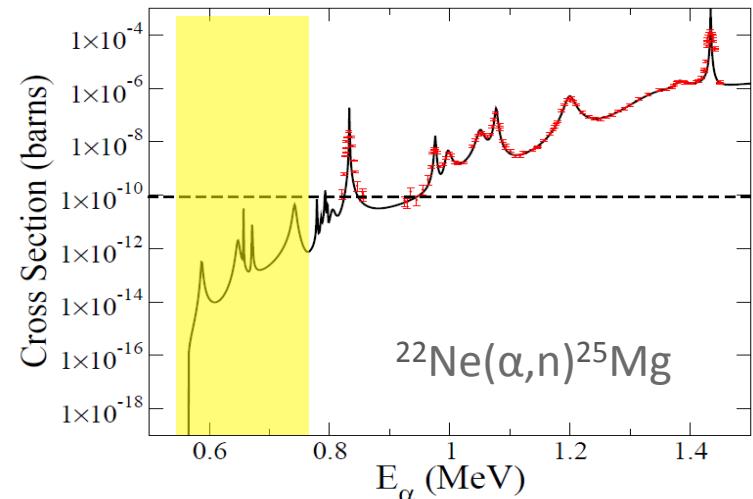
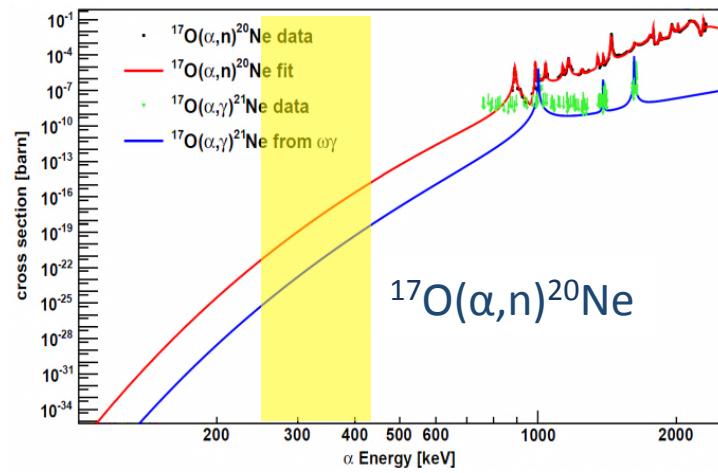


# S-process neutron sources

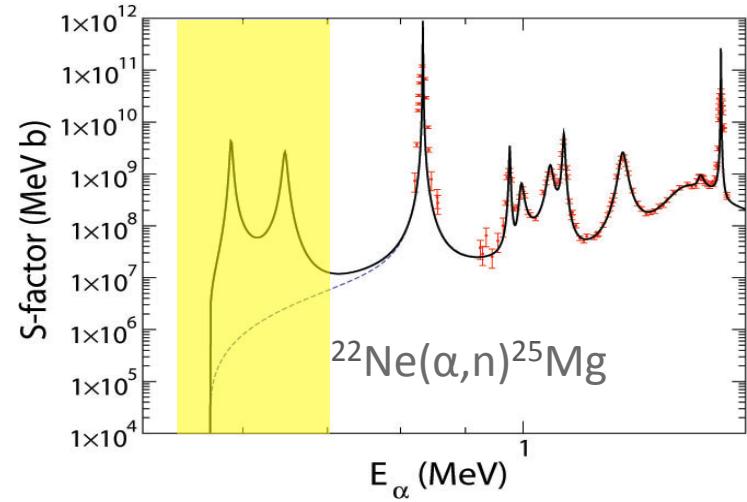
in AGB stars, He/H zone



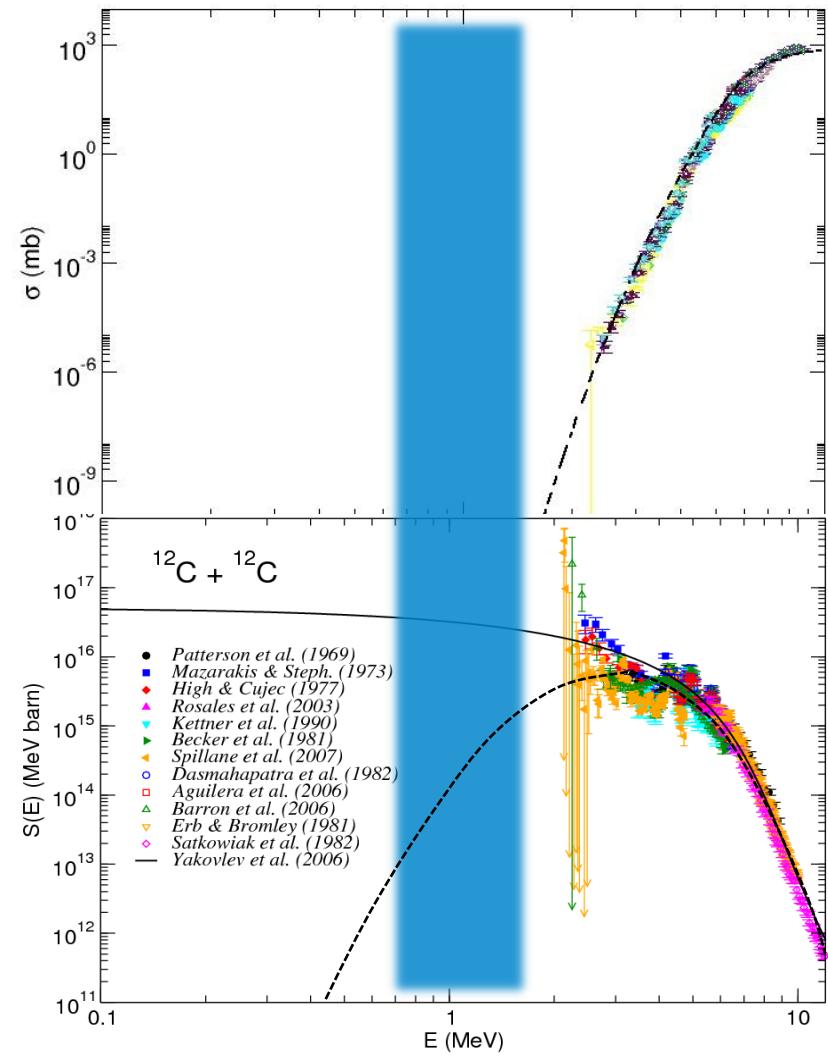
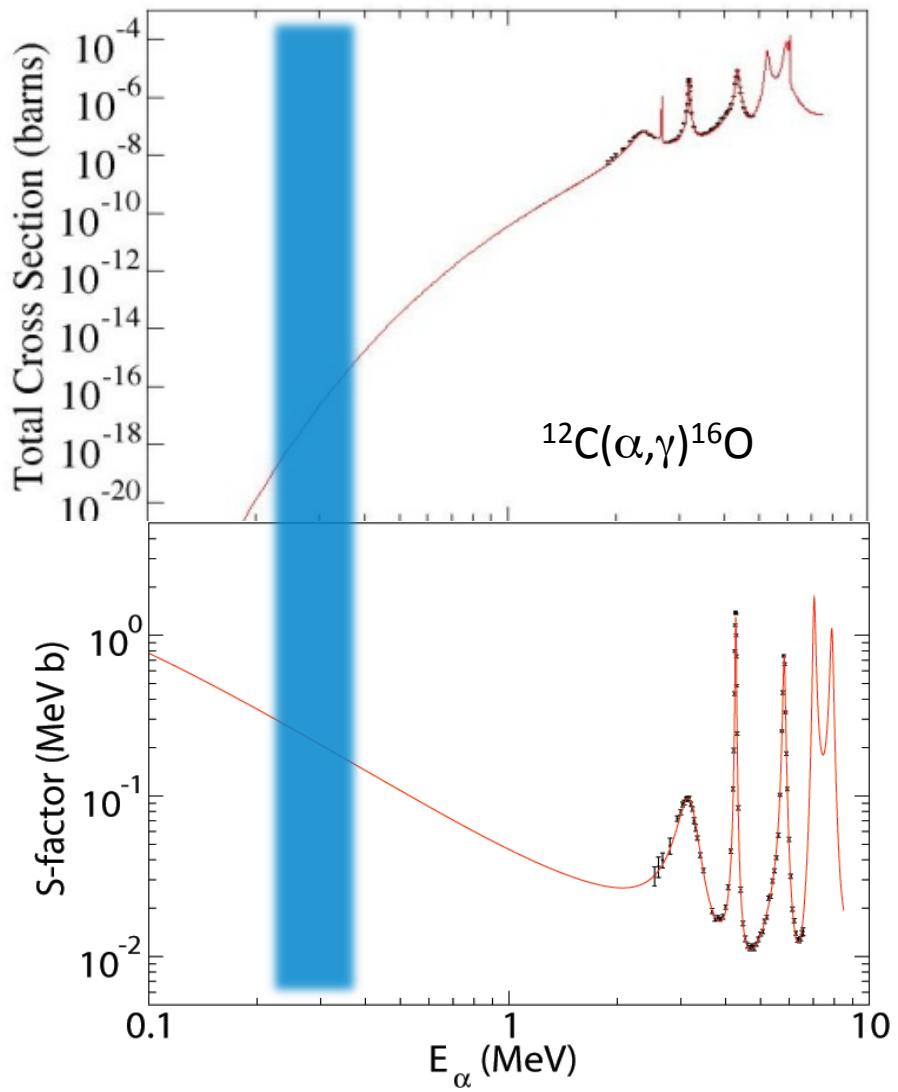
in RGB stars C-shell



in AGB star He-flash, RGB stars He-core



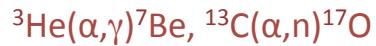
# Carbon burning reactions





# DIANA program & priorities

## Neutrino Physics



Solar neutrino production and neutron source for main s-process. (2-3 years)

## Neutron Sources and Neutron Poisons



Neutron source and poison for weak s-process (3-4 years)

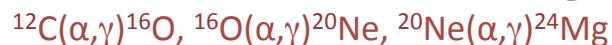
## CNO neutrinos and Solar Metallicity



CNO reaction measurement near Gamow range (2-4 years)

**Total program: (16-28 years)**

## Stellar helium burning and alpha clustering



Measuring cross section and resonance structure near threshold energies (3-5 years)

## From Late Stellar Evolution to Supernova



Late stellar nucleosynthesis, s-process neutron source, type Ia SN & superburst ignition (4-6 years)

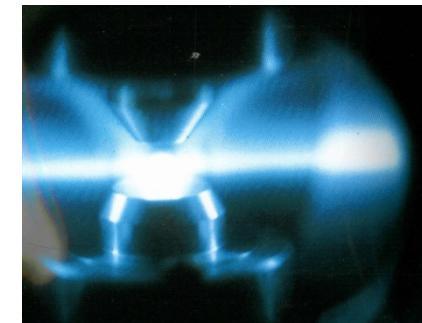
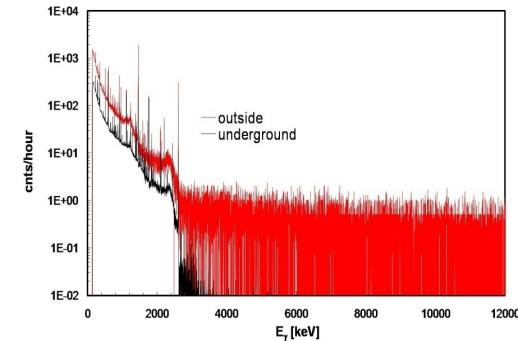
## Nuclear Plasma Physics



Detector testing, accelerator calibration, electron screening effects in gases and solids (2-6 years)

# Requirements

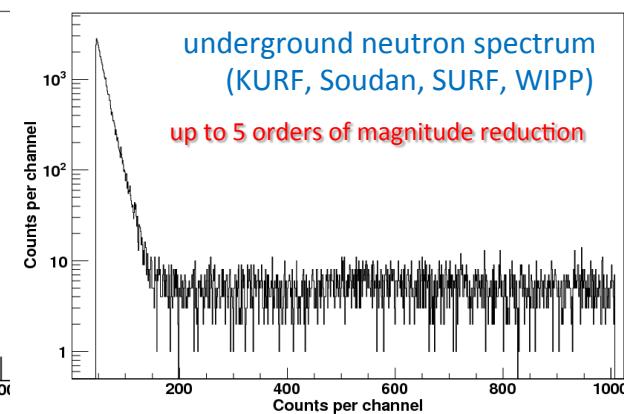
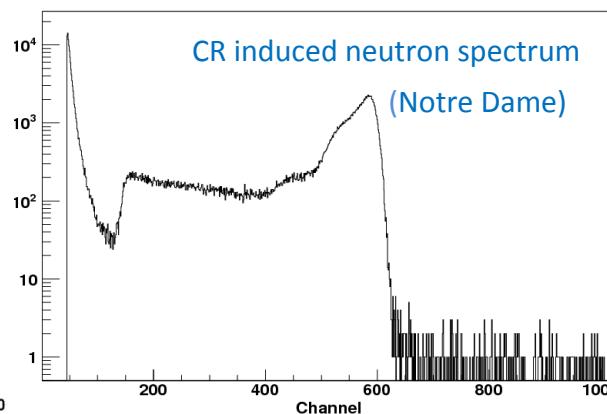
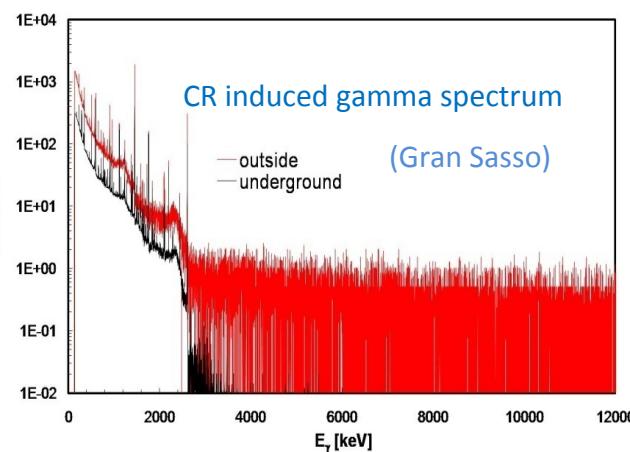
- **Background reduction in detector devices**
  - Cosmic radiation background
  - Environmental decay background
  - Beam induced background
- **Increase of reaction yield**
  - Increasing beam intensity
  - Improving target stoichiometry
  - Improving target stability
- **Long term measurements**
  - Long term operation support
  - Long term accessibility of facility
  - Broad community



# Underground background reduction

- Low detector background

Background will primarily be reduced by several orders of magnitude through CR shielding in deep environment.



- Target techniques

Target stoichiometry, design,  
and target stability under  
intense beam conditions

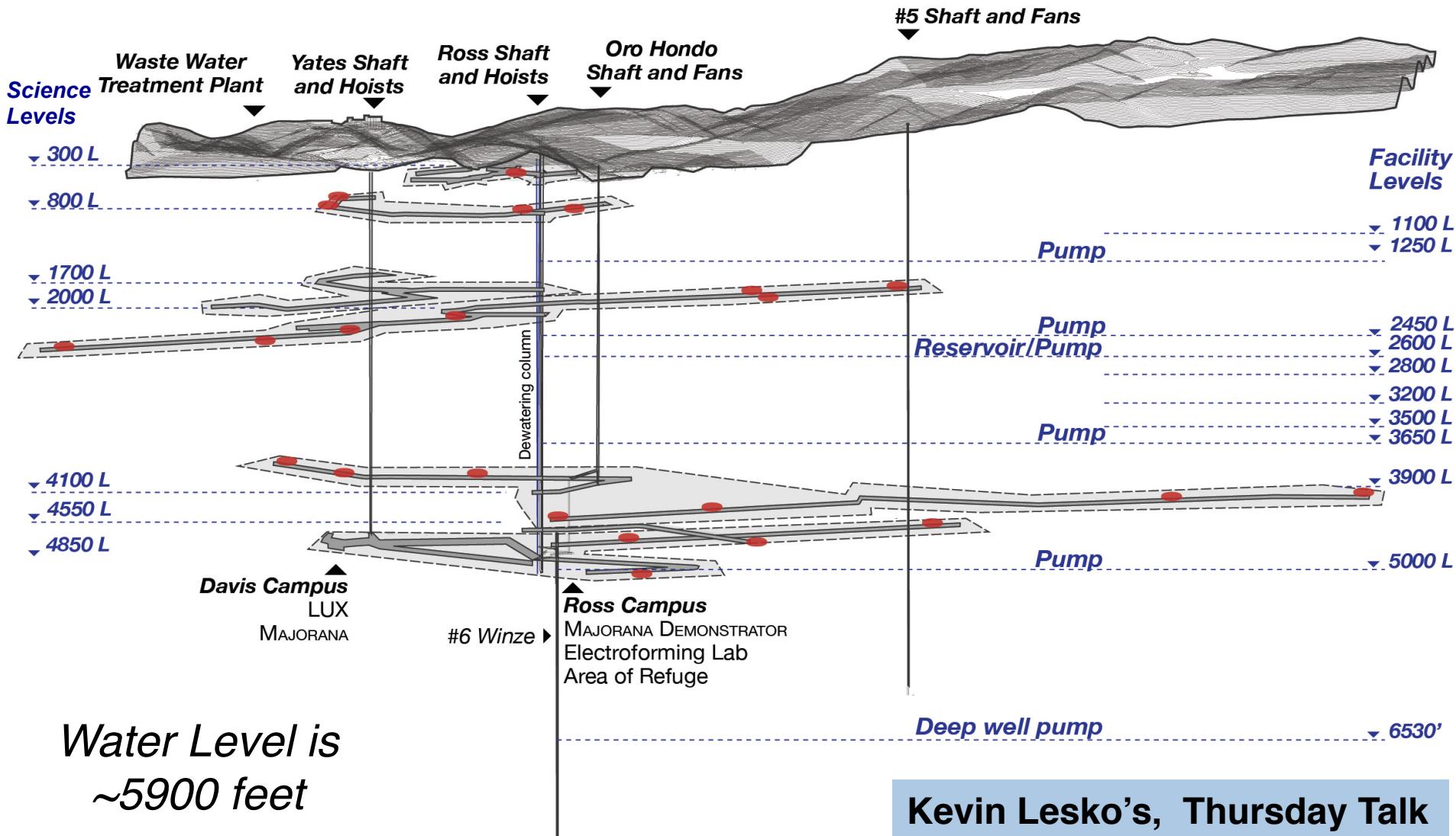
- Detector design

Detection system with enhanced  
efficiency and active background  
rejection capabilities



# SURF Science and Facility Operations Levels

8000 feet deep, ~370 miles of tunnels total, SURF maintains ~12 miles

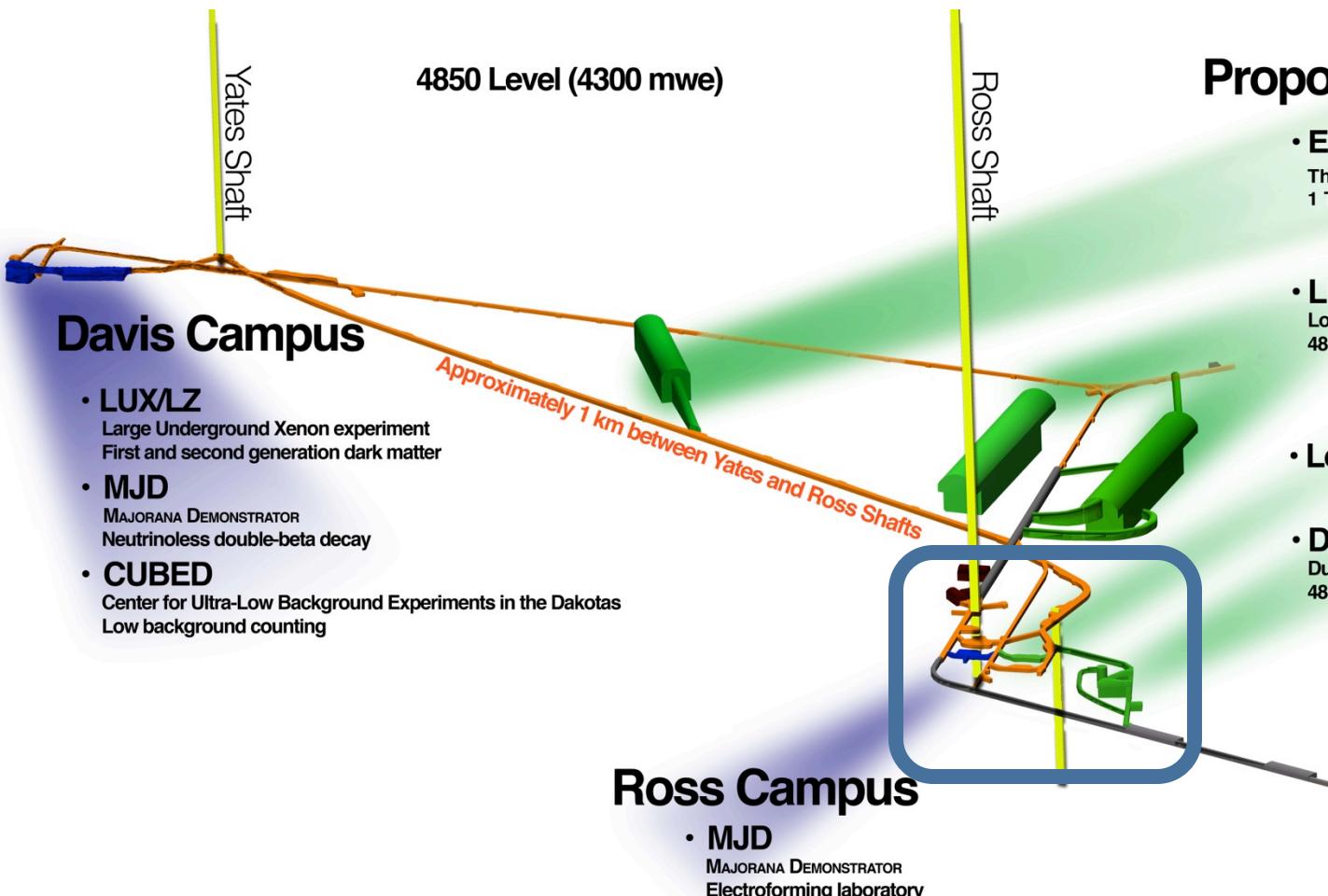


Water Level is  
~5900 feet

Kevin Lesko's, Thursday Talk



# SURF site selection



## Proposed Laboratories

- Experiment Hall**  
Third generation dark matter experiment  
1 T neutrinoless double-beta decay experiment

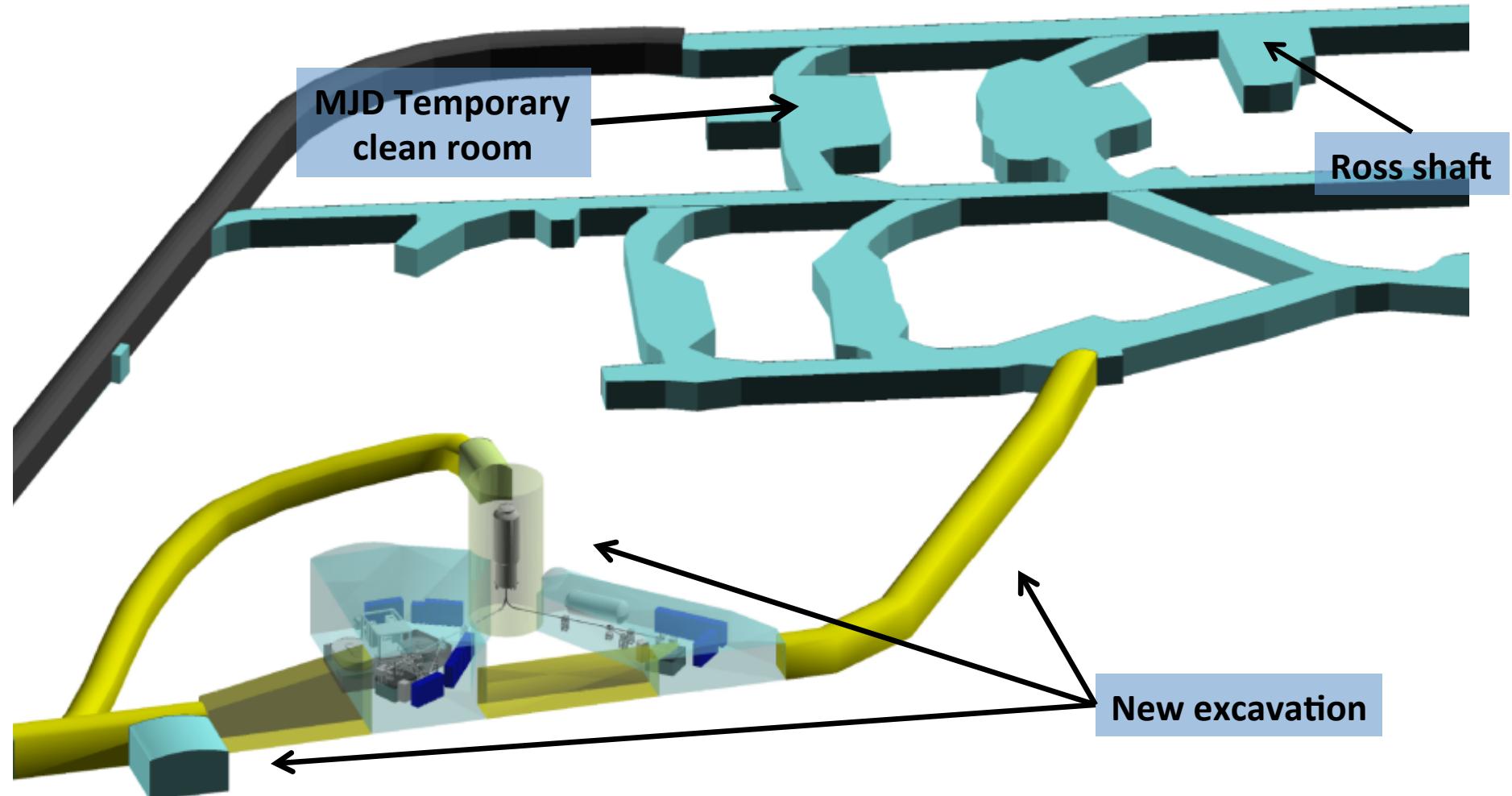
- LBNE**  
Long-Baseline Neutrino Experiment  
4850 Level liquid argon

- Low Background Counting**

- DIANA**  
Dual Ion Accelerators for Nuclear Astrophysics  
4850 Level DIANA Laboratory



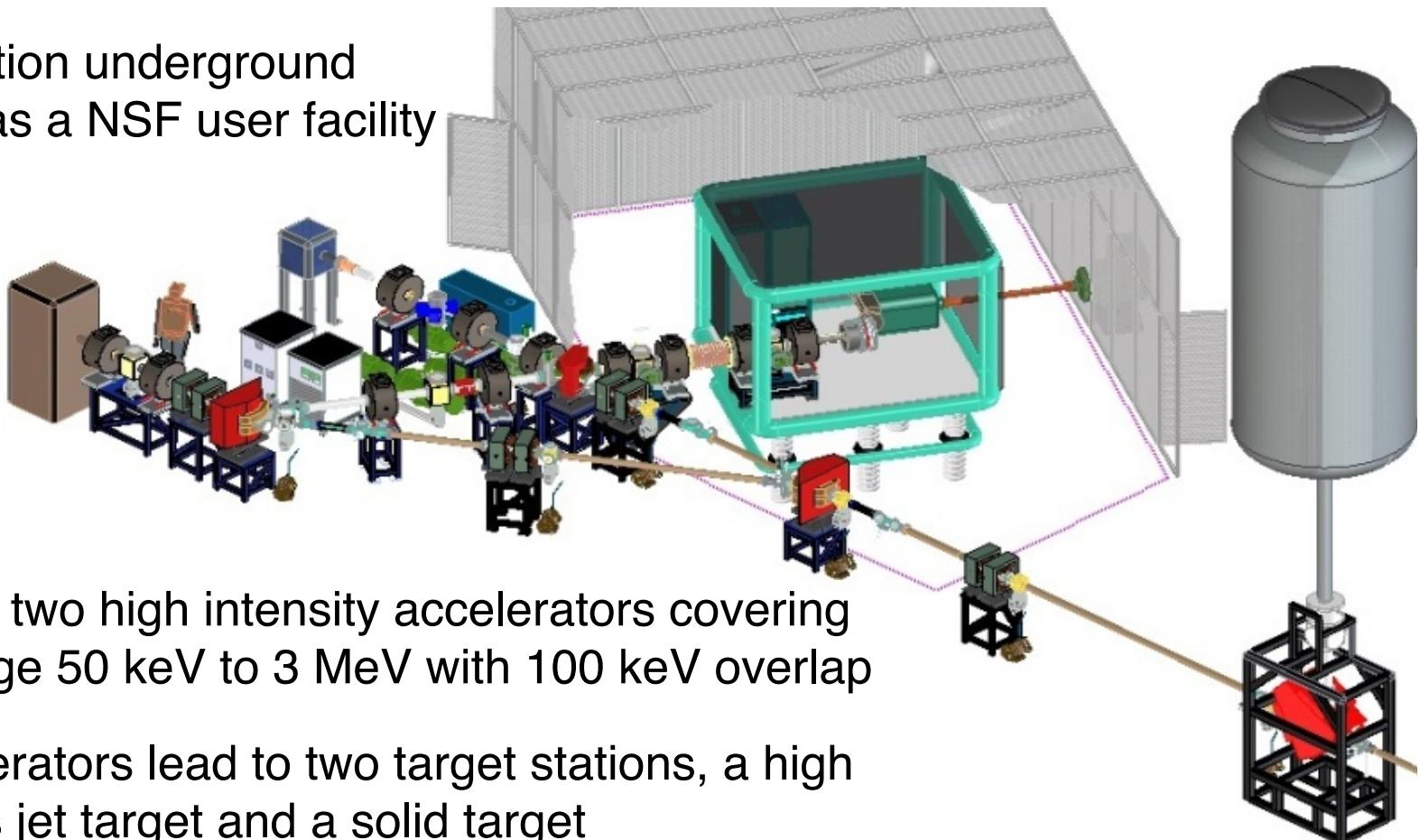
# DIANA proposed cavity location





# DIANA design

Next generation underground accelerator as a NSF user facility

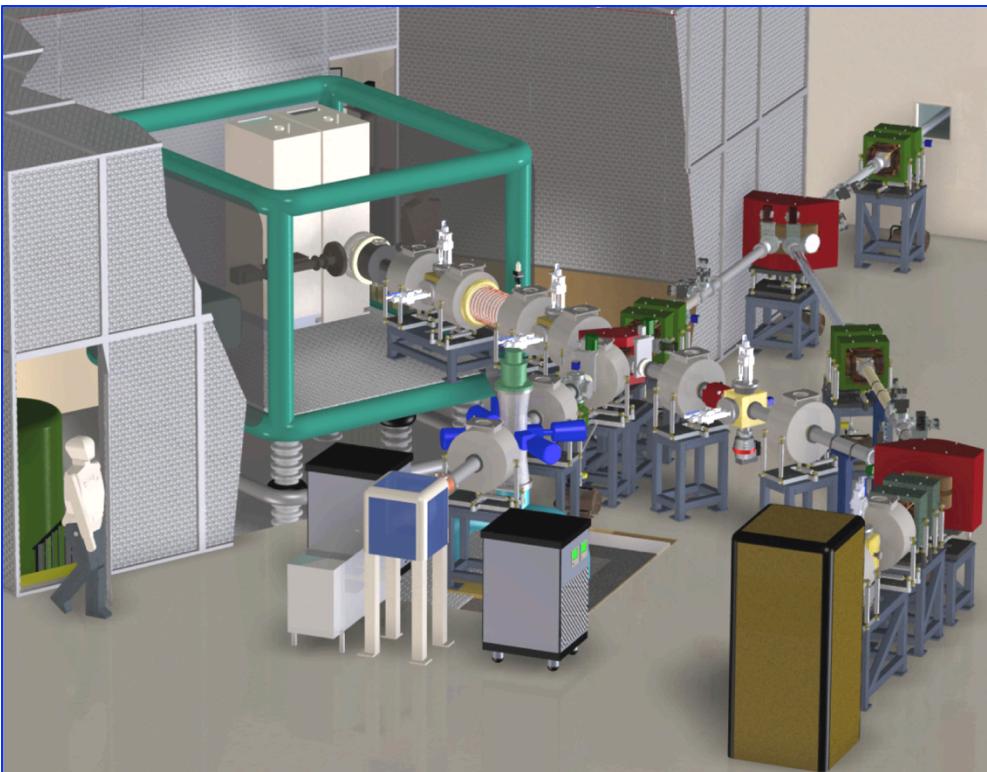


Consists of two high intensity accelerators covering energy range 50 keV to 3 MeV with 100 keV overlap

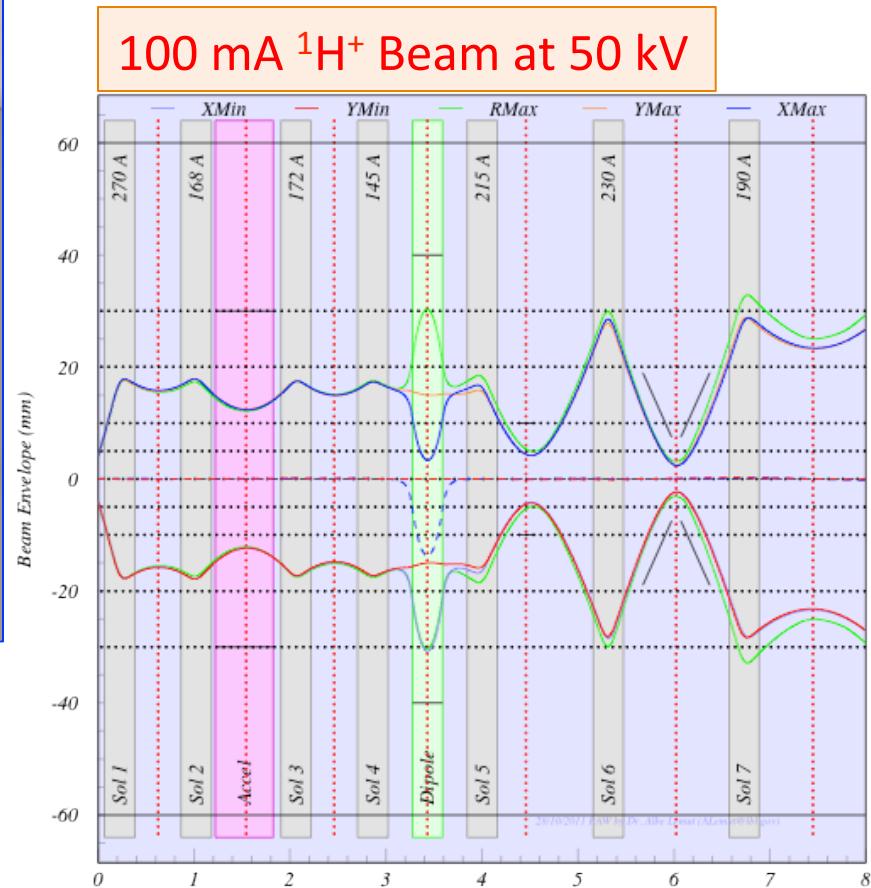
Both accelerators lead to two target stations, a high density gas jet target and a solid target

Detection is via optimized configurations of HPGe detectors or  $^3\text{He}$  neutron counters

# Low Energy 400kV accelerator

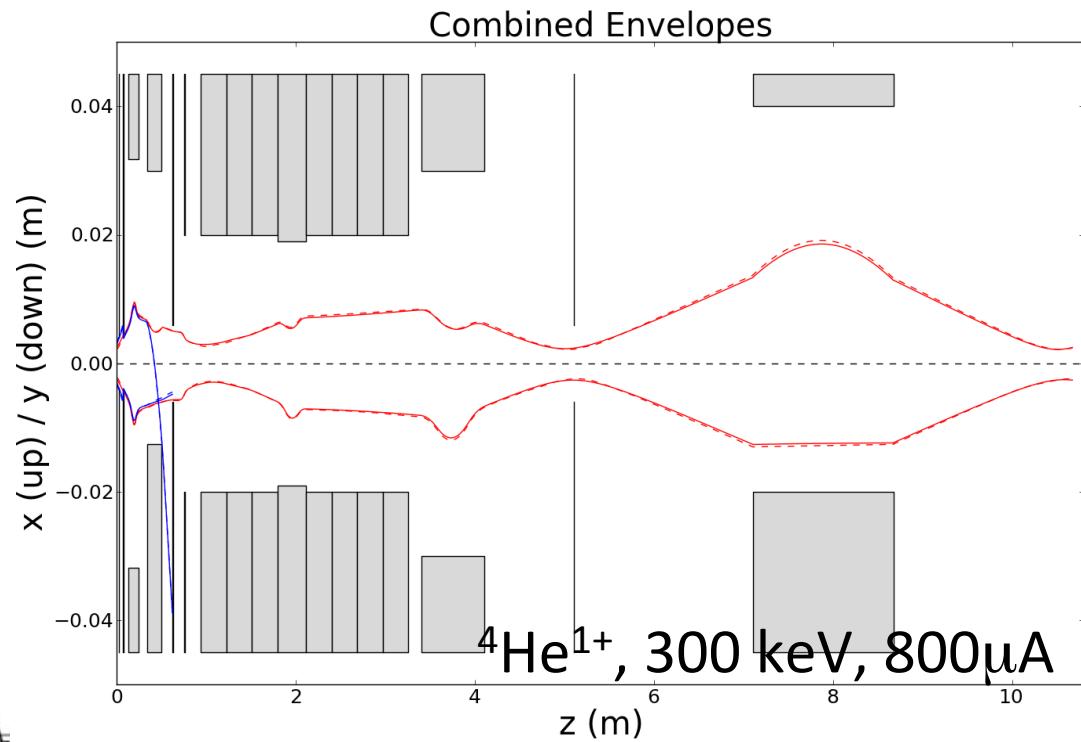
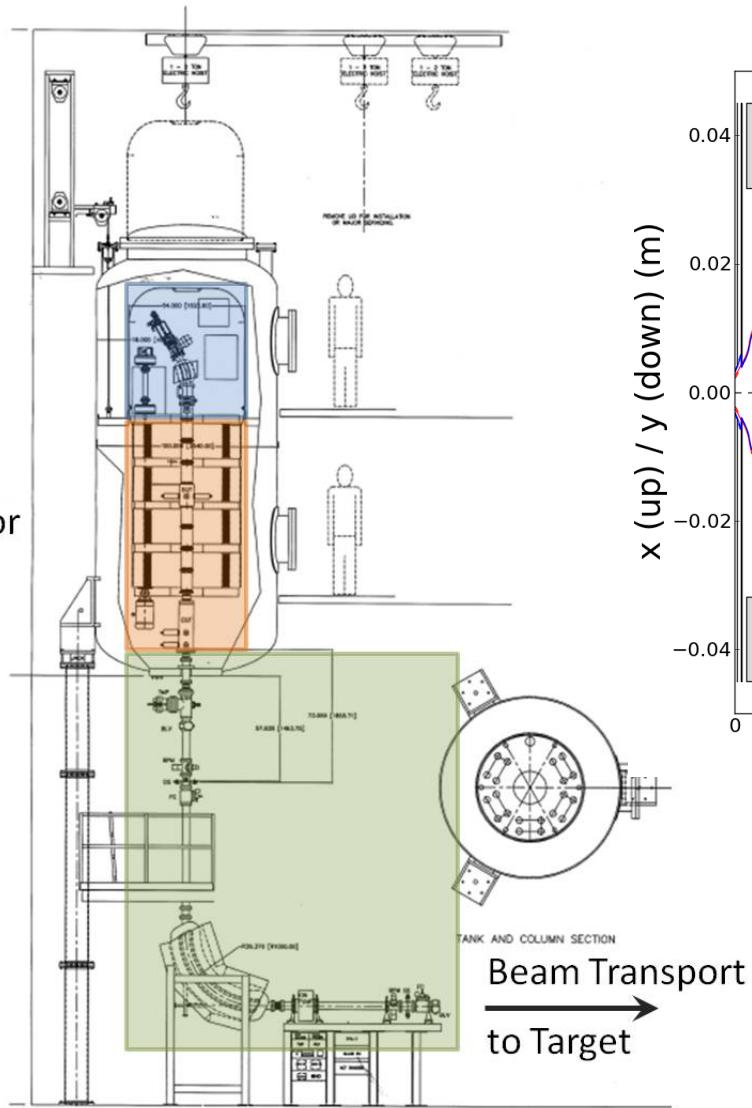


- Open air platform
- p, d, He beams
- 100 mA at 50 keV
- Designed at LBNL



# High Energy 3 MeV accelerator

Front End  
Accelerator  
Bending-  
Section

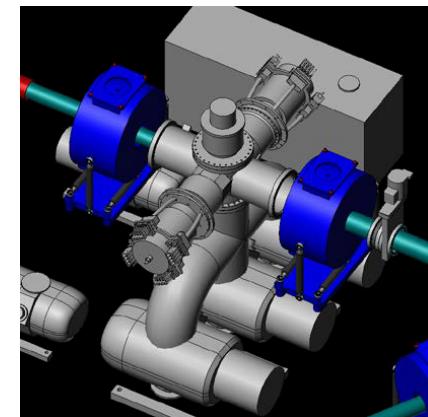
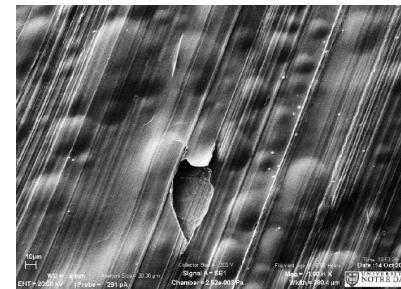


- Customized NEC accelerator
- Variable voltage gradient
- Beam  $A \leq 20$
- Intensity  $\sim 1 \text{ mA}$

# Targets and detectors

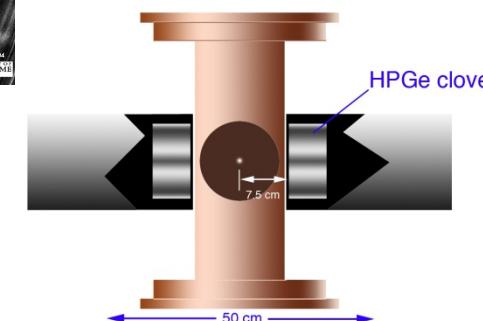
## Gas Jet Target:

- Designed to withstand upto 5 kW
- High speed gas to minimize diffusion ( $\sim 2000$  m/s)
- Jet diameter: 1cm
- Jet thickness:  $10^{18}$  at/cm<sup>2</sup>
- Calorimeter



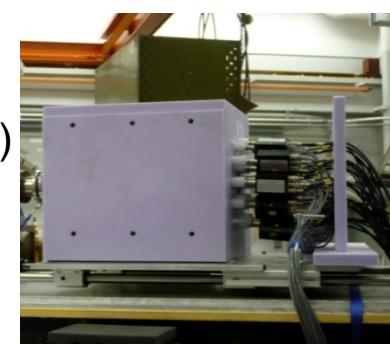
## Solid target:

- Designed to withstand 500W
- Raster beam to distribute power
- Ready for beam size up to 1 cm



## Gamma detection:

- Two large clover HPGe detectors (Gas target)
  - 4x 70x70mm crystals
- One large clover surrounded by NaI annulus (solid target)

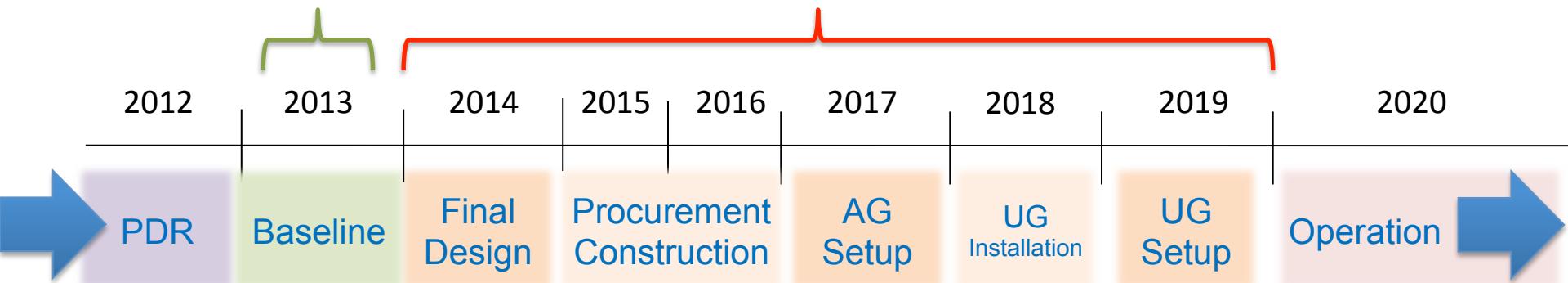


## Neutron detection:

- ~45% efficiency neutron detector
  - $^3\text{He}$  tube embedded in polyethylene



# Status and path forward



- April – NSF request for possible reductions
- Early June - NSF meeting to discuss funding options
- Mid June - Final PAC meeting and strong approval of DIANA project
- End of June – Informed by NSF, DIANA can not be funded at this time due to sequestration
- Final reports and designs delivered to NSF - Wait

# CASPAR while we wait

## Compact Accelerator System for Performing Astrophysical Research:

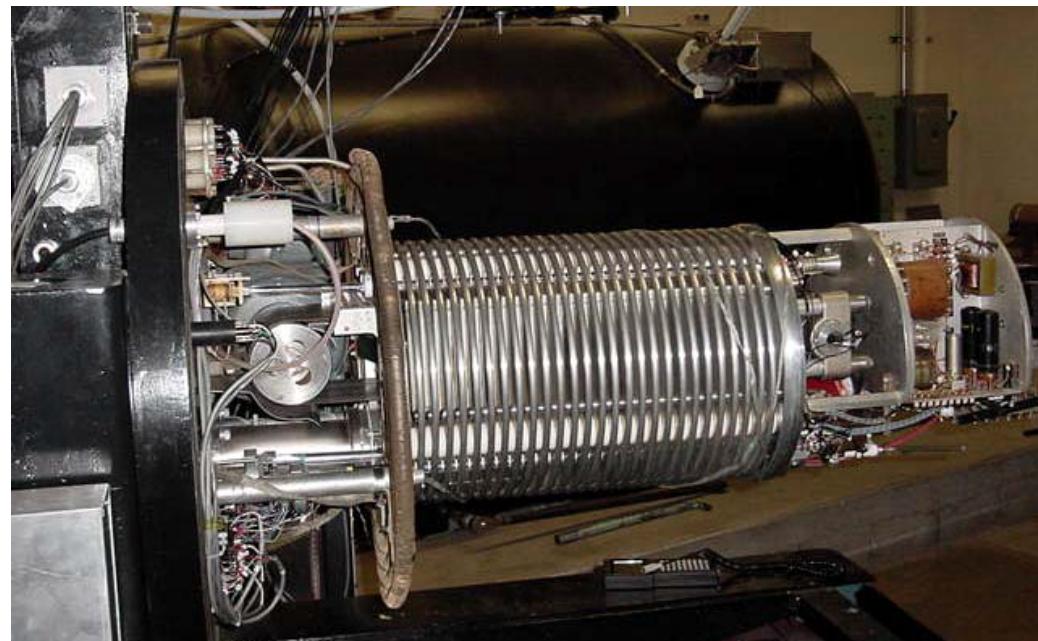
- Relocation of Notre Dame JN accelerator
- Effective energy range  $\sim 100 \text{ keV} - 1 \text{ MeV}$
- Beam production in range of  $100 - 150 \mu\text{A}$  protons and alphas
- Current plan for refurbishment and upgrade
- Recirculating windowless gas target

### Initial program

- $^{13}\text{C}(\alpha, n)^{17}\text{O}$  and  $^{22}\text{Ne}(\alpha, n)^{25}\text{Mg}$

### Collaborative institutions

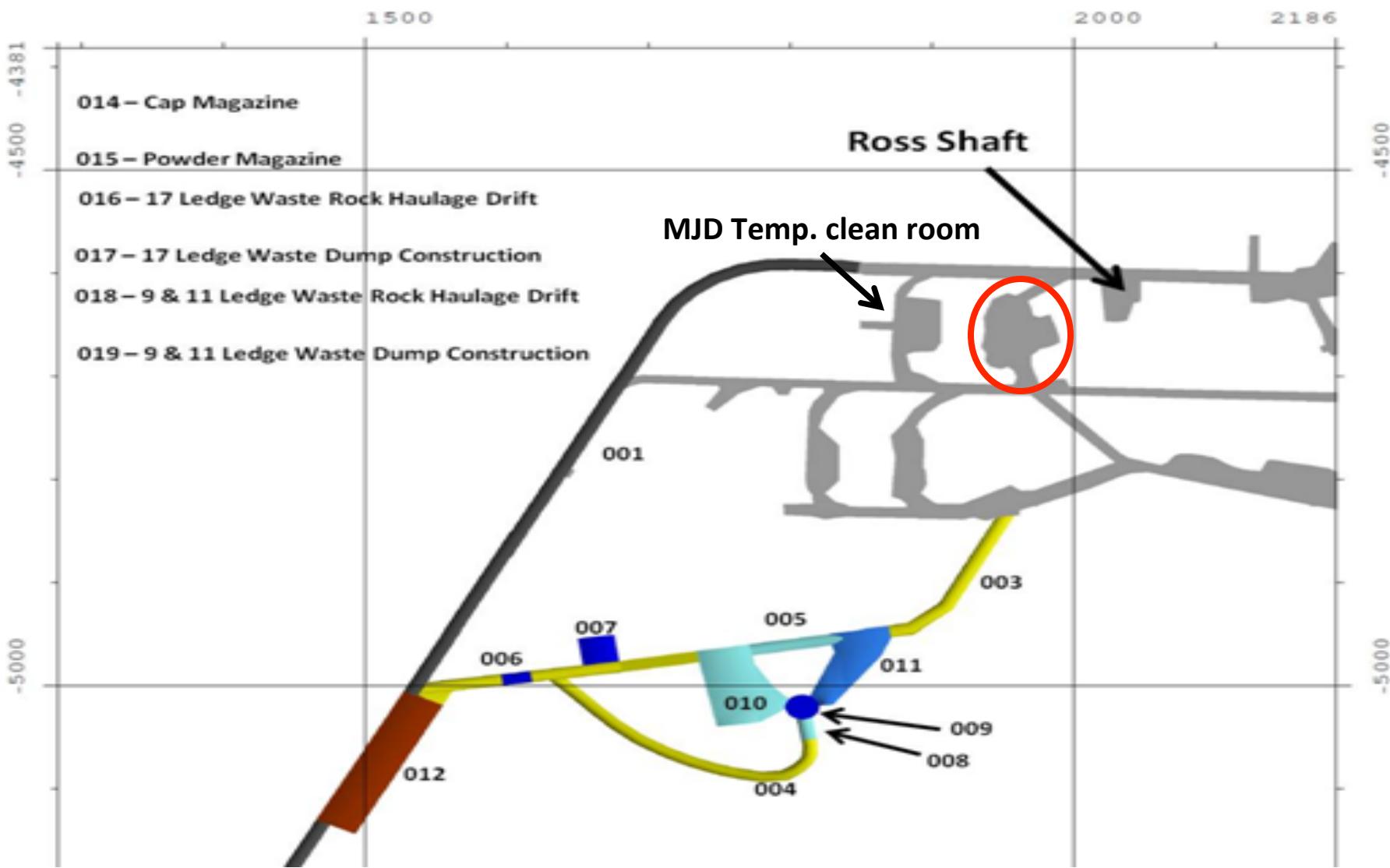
- South Dakota School of Mines
- University of Notre Dame
- Colorado School of Mines
- University of North Carolina Chapel Hill



**Start date January 1<sup>st</sup> 2014 (18-24 month duration)**



# CASPAR proposed location





# Summary

- Baseline for DIANA preliminary design achieved
- External review committee approval and strong support
  - Agreement of DIANA as a world leading facility
- User community interest identified
- Ready for final design phase prior to procurements
- Bit of a cash flow problem – NSF not able to fund at this time
  - No timeline given as of yet on delay
- CASPAR will be used as a demonstrator for DIANA
- Achievable science to be done while waiting for funding
- Will be used to validate background radiation simulations
- Proposed cavity allows for possible upgrades and expansion